Claim Amendments

1. (Presently Amended, Twice) A method for reducing a spurious signal in a nuclear magnetic resonance (NMR) measurement, comprising:

inducing a static magnetic field in a volume to polarize spins of nuclei therein;

inducing an RF magnetic field in the volume in accordance with a pulse sequence;

acquiring a sequence of signals, including at least a first signal and a second signal, generated in the volume in response to the pulse sequence, the at least first and second signals ~~each signal~~ in the acquired sequence including a spurious signal component and a spin echo component;

combining at least ~~a~~ the first signal and ~~a~~ the second signal of the acquired sequence, the combination generating a corrected signal having a reduced spurious signal component.

2. (Original) The method as recited in claim 1, wherein the corrected signal is generated from a linear combination of at least the first signal and the second signal.

3. (Original) The method as recited in claim 2, wherein the linear combination is the average of at least the first signal and the second signal.

4. (Original) The method as recited in claim 1, wherein the second signal is adjacent the first signal in the acquired sequence.

5. (Original) The method as recited in claim 1, wherein the second signal is a next nearest neighbor of the first signal in the acquired sequence.

6. (Original) The method as recited in claim 1, wherein a time delay between the first signal and the second signal in the acquired sequence is less than 10 milliseconds.

7. (Original) The method as recited in claim 1, wherein a time delay between the first signal and the second signal in the acquired sequence is in the range of 0.5 to 5 milliseconds.

8. (Original) The method as recited in claim 1, comprising computing an NMR parameter of the volume using the corrected signal.

9. (Original) The method as recited in claim 8, wherein the NMR parameter is a T_2 distribution.

10. (Original) The method as recited in claim 8, comprising deriving a geological characteristic of the volume based on the computed NMR property.

11. (Original) The method as recited in claim 10, wherein the geological characteristic is porosity.

12. (Original) The method as recited in claim 1, wherein the pulse sequence comprises a plurality of inversion pulses, and wherein at least one of the inversion pulses is phase alternated relative to the others.

13. (Original) The method as recited in claim 1, wherein the pulses of the pulse sequence are arranged to compensate for spin dynamics errors.

14. (Original) The method as recited in claim 1, wherein the pulse sequence comprises a plurality of inversion pulses arranged in a repeating phase pattern, and wherein the repeating phase pattern is six inversion pulses arranged to induce a phase pattern of six spin echo signals in accordance with the following:

$+X_1(-y_1)-X_2(+y_2)-X_3(-y_3)-X_4(+y_4)+X_5(-y_5)+X_6(+y_6)$

wherein the bold uppercase terms represent direction of the inversion pulses, and the italicized lowercase terms represent direction of the induced spin echo signals in a rotating frame of reference.

15. (Original) The method as recited in claim 14, wherein the linear combination is selected from the group consisting of:

(a) $lc_1 = \frac{1}{2}(e_i + e_j)\ \forall\, i = 1, 4, 7, \ldots,\ j = 3, 6, 9, \ldots;$

(b) $lc_2 = \frac{1}{2}(e_i + e_j)\ \forall\, i = 2, 5, 8, \ldots,\ j = 3, 6, 9, \ldots;$

(c) $lc_3 = \frac{1}{2}(e_i + e_j)\ \forall\, i = 3, 6, 9, \ldots,\ j = 4, 7, 10, \ldots;$

(d) $lc_4 = \frac{1}{2}(e_i + e_j)\ \forall\, i = 3, 6, 9, \ldots,\ j = 5, 8, 11, \ldots;$

wherein *lc* represents the linear combination, and *e* represents the induced spin echo signal.

16. (Original) The method as recited in claim 1, wherein the pulse sequence comprises a plurality of inversion pulses arranged in a repeating phase pattern, and wherein the repeating phase pattern is three inversion pulses arranged to induce a phase pattern of three spin echo signals in accordance with the following:

$+\mathbf{Y}_1(+y_1)-\mathbf{Y}_2(+y_2)-\mathbf{Y}_3(+y_3)$

wherein the bold uppercase terms represent direction of the inversion pulses, and the italicized lowercase terms represent direction of the induced spin echo signals in a rotating frame of reference.

17. (Original) The method as recited in claim 1, wherein the pulse sequence comprises a plurality of inversion pulses arranged in a repeating phase pattern, and wherein the repeating phase pattern is three inversion pulses arranged to induce a phase pattern of three spin echo signals in accordance with the following:

$+\mathbf{Y}_1(+y_1)+\mathbf{Y}_2(+y_2)-\mathbf{Y}_3(+y_3)$

wherein the bold uppercase terms represent direction of the inversion pulses, and the italicized lowercase terms represent direction of the induced spin echo signals in a rotating frame of reference.

18. (Original) The method as recited in claim 1, comprising computing a first reconstructed signal and a second reconstructed signal from the corrected signal, the first and second reconstructed signals representative of the respective spin echo components of the first and second signals of the acquired sequence.

19. (Amended, Once) A method of reducing a ringing signal generated while measuring a nuclear magnetic resonance (NMR) property of an earth formation adjacent a borehole, comprising:

inserting a logging tool into the borehole;

applying a static magnetic field to polarize spins of nuclei within a volume of the earth formation;

applying an RF magnetic field to the volume in accordance with a pulse sequence comprising a plurality of inversion pulses arranged in a repeating phase pattern;

acquiring, after each of the plurality of pulses in the pulse sequence, a spin echo signal induced in the volume, the acquisition forming a measurement set comprising a plurality of spin echo signals, each spin echo signal including a spin echo component and a ringing component; and

combining spin echo signals within the measurement set to reduce the ringing components, the combination generating a corrected measurement set.

20. (Original) The method as recited in claim 19, wherein the combining comprises forming a linear combination of spin echo signals within the measurement set.

21. (Original) The method as recited in claim 19, comprising determining, from the corrected measurement set, an NMR parameter of the earth formation.

22. (Original) The method as recited in claim 21, comprising deriving from the NMR parameter a property of the earth formation.

23. (Original) The method as recited in claim 19, wherein the acquiring is performed while drilling the borehole.

24. (Original) The method as recited in claim 19, wherein at least one of the inversion pulses in the repeating phase pattern is phase alternated relative to the others.

25. (Original) The method as recited in claim 19, wherein the inversion pulses in the repeating phase pattern are arranged to compensate for spin dynamics errors.

26. (Original) The method as recited in claim 19, wherein the repeating phase pattern of inversion pulses is six inversion pulses arranged to induce a pattern of six spin echo signals in accordance with the following:

$$+\mathbf{X}_1(-y_1)-\mathbf{X}_2(+y_2)-\mathbf{X}_3(-y_3)-\mathbf{X}_4(+y_4)+\mathbf{X}_5(-y_5)+\mathbf{X}_6(+y_6)$$

wherein the bold uppercase terms represent direction of the inversion pulses, and the italicized lowercase terms represent direction of the induced spin echo signals in a rotating frame of reference.

27. (Original) The method as recited in claim 26, wherein the combining comprises forming a linear combination of spin echo signals within the measurement set, and the linear combination is selected from the group consisting of:

(a) $lc_1 = ½(e_i + e_j)\ \forall\, i = 1, 4, 7, \ldots,\ j = 3, 6, 9, \ldots;$

(b) $lc_2 = ½(e_i + e_j)\ \forall\, i = 2, 5, 8, \ldots,\ j = 3, 6, 9, \ldots;$

(c) $lc_3 = ½(e_i + e_j)\ \forall\, i = 3, 6, 9, \ldots,\ j = 4, 7, 10, \ldots;$

(d) $lc_4 = ½(e_i + e_j)\ \forall\, i = 3, 6, 9, \ldots,\ j = 5, 8, 11, \ldots;$

wherein *lc* represents the linear combination, and *e* represents the induced spin echo signal.

28. (Original) The method as recited in claim 19, wherein the repeating phase pattern of inversion pulses is three inversion pulses arranged to induce a pattern of three spin echo signals in accordance with the following:

$+\mathbf{Y}_1(+y_1)-\mathbf{Y}_2(+y_2)-\mathbf{Y}_3(+y_3)$

wherein the bold uppercase terms represent direction of the inversion pulses, and wherein the italicized lowercase terms represent direction of the induced spin echo signals in a rotating frame of reference.

29. (Original) The method as recited in claim 19, wherein the repeating phase pattern of inversion pulses is three inversion pulses arranged to induce a pattern of three spin echo signals in accordance with the following:

$+\mathbf{Y}_1(+y_1)+\mathbf{Y}_2(+y_2)-\mathbf{Y}_3(+y_3)$

wherein the bold uppercase terms represent direction of the inversion pulses, and the italicized lowercase terms represent direction of the induced spin echo signals in a rotating frame of reference.

30. (Original) The method as recited in claim 19, comprising computing a set of first reconstructed signals from the corrected measurement set, the set of reconstructed signals representative of the respective spin echo components of the acquired spin echo signals.

31. (Amended, Once) A method for determining an earth formation property from nuclear magnetic resonance (NMR) measurements, comprising:

acquiring a first measurement set of spin echo signals induced in the earth formation by a first RF pulse sequence, the spin echo signals including a spin echo component and a noise component;

linearly combining spin echo signals within the first measurement set to reduce the noise component, the combination generating a first corrected measurement set;

determining an NMR parameter based on the first corrected measurement set; and

deriving the earth formation property from the NMR parameter.

32. (Original) The method as recited in claim 31, wherein the linearly combining is restricted to only combinations of spin echo signals that reduce the noise component.

33. (Original) The method as recited in claim 31, wherein the NMR parameter is a T_2 distribution.

34. (Original) The method as recited in claim 31, wherein the acquiring is performed while drilling a borehole traversing the earth formation.

35. (Original) The method as recited in claim 31, comprising:

acquiring a second measurement set of spin echo signals induced in the earth formation by a second RF pulse sequence, the second RF pulse sequence being phase alternated relative to the first RF pulse sequence, the spin echo signals of the second measurement set including a spin echo component and a noise component;

linearly combining spin echo signals within the second measurement set to reduce the noise component, thereby generating a second corrected measurement set;

combining the first corrected measurement set with the second corrected measurement set; and

determining the NMR parameter based on the first and second corrected measurement sets.

36. (Original) The method as recited in claim 31, wherein the first RF pulse sequence comprises a plurality of inversion pulses arranged in a repeating phase pattern, and wherein the repeating phase pattern is six inversion pulses arranged to induce a pattern of six spin echo signals in accordance with the following:

$+\mathbf{X}_1(-y_1)-\mathbf{X}_2(+y_2)-\mathbf{X}_3(-y_3)-\mathbf{X}_4(+y_4)+\mathbf{X}_5(-y_5)+\mathbf{X}_6(+y_6)$

wherein the bold uppercase terms represent direction of the inversion pulses, and the italicized lowercase terms represent direction of the induced spin echo signals in a rotating frame of reference.

37. (Original) The method as recited in claim 36, wherein linearly combining comprises forming at least one linear combination from the group consisting of:

(a) $lc_1 = ½(e_i + e_j)\ \forall\, i = 1, 4, 7, \ldots,\ j = 3, 6, 9, \ldots;$

(b) $lc_2 = ½(e_i + e_j)\ \forall\, i = 2, 5, 8, \ldots,\ j = 3, 6, 9, \ldots;$

(c) $lc_3 = ½(e_i + e_j)\ \forall\, i = 3, 6, 9, \ldots,\ j = 4, 7, 10, \ldots;$

(d) $lc_4 = ½(e_i + e_j)\ \forall\, i = 3, 6, 9, \ldots,\ j = 5, 8, 11, \ldots;$

wherein *lc* represents the linear combination, and *e* represents the induced spin echo signal.

38. (Original) The method as recited in claim 31, wherein the first RF pulse sequence comprises a plurality of inversion pulses arranged in a repeating phase pattern, and wherein the repeating phase pattern is three inversion pulses arranged to induce a pattern of three spin echo signals in accordance with the following:

$+\mathbf{Y}_1(+y_1)-\mathbf{Y}_2(+y_2)-\mathbf{Y}_3(+y_3)$

wherein the bold uppercase terms represent direction of the inversion pulses, and the italicized lowercase terms represent direction of the induced spin echo signals in a rotating frame of reference.

39. (Original) The method as recited in claim 31, wherein the first RF pulse sequence comprises a plurality of inversion pulses arranged in a repeating phase pattern, and wherein the repeating phase pattern is three inversion pulses arranged to induce a pattern of three spin echo signals in accordance with the following:

$+\mathbf{Y}_1(+y_1)+\mathbf{Y}_2(+y_2)-\mathbf{Y}_3(+y_3)$

wherein the bold uppercase terms represent direction of the inversion pulses, and the italicized lowercase terms represent direction of the induced spin echo signals in a rotating frame of reference.

40. (Original) The method as recited in claim 31, comprising computing a first reconstructed signal and a second reconstructed signal from the corrected signal, the first and second reconstructed signals representative of the respective spin echo components of the first and second signals of the acquired sequence.

41. (New) The method as recited in claim 1, wherein the first and second signals are closely spaced with each other.

42. (New) The method as recited in claim 19, wherein the second signal is adjacent the first signal in the acquired sequence.

43. (New) The method as recited in claim 19, wherein the first and second signals are closely spaced with each other.

44. (New) The method as recited in claim 31, wherein the second signal is adjacent the first signal in the acquired sequence.

45. (New) The method as recited in claim 31, wherein the first and second signals are closely spaced with each other.